EXHIBIT 6

EXPERT REPORT OF DAVID CROWE
(Bellwether 3)

In re Flint Water Cases,
U.S. District Court for the Eastern District of Michigan
Civil Action No.5:16-cv-10444-JEL-MKM
(consolidated docket)

Walters, et al. v. Snyder, et al., Civil Action No.5: 17-cv-10164-JEL-MKM

"Bellwether 3 Trial"

By:
David C. Crowe, Ph.D.
David Crowe Consulting, LLC
5835 Windknoll Court, Cincinnati, OH 45243-2966

Submitted to:
Andreas Ringstad, Esq.
Campbell Conroy and O'Neil, P.C.
1205 Westlakes Dr., Suite 330, Berwyn, PA 19312

Mark Ter Molen, Esq. and Matthew Sostrin, Esq.
Mayer Brown LLP
71 S. Wacker Drive, Chicago, IL 60606

July 26, 2023

1. INTRODUCTION

At the request of Veolia North America's attorneys, I reviewed the Bellwether 3 "Expert Report of Dr. Larry L. Russell" dated January 3, 2023. I offer opinions in response to Dr. Russell's report herein. Dr. Russell's Bellwether 3 report also refers to his supplemental report in the class case dated October 18, 2022, which I addressed in my February 3 and March 14, 2023 reports, and I am prepared to offer all of those opinions at trial as well.

I reserve the right to supplement and amend my opinions based on and subject to review and analysis of additional discovery information I receive.

This report is respectfully submitted by,

David C. Crowe, Ph.D.
davecrowe513@gmail.com
Phone: (513) 272-6606

I have reached the opinions herein, and the opinions in my February 3 and March 14, 2023 reports, based on my review, investigation, and analysis of relevant materials, in light of my knowledge, training, and experience, and I offer the following opinions to a reasonable degree of scientific and engineering certainty.

Dr. David C. Crowe
David Crowe Consulting LLC
Cincinnati, Ohio
July 26, 2023

2. OPINIONS

2.1 <u>Opinion 1</u> – Sample sections of piping from two homes in Flint were removed by Dr. Russell, shipped and stored poorly, thereby precluding further examination and analysis that would produce meaningful results.

Pipe samples, comprising all accessible galvanized steel pipe and any copper pipe with external corrosion product, were cut out from the two Flint homes by Dr. Russell, thereby removing all accessible evidence of drinking water piping. Some sections could be identified according to photos I took when I performed my visual inspection in 2020 (**1,2**). The locations of others could not be determined. The sections had not been labeled (except for a letter), which is one of the simplest fundamental practices of sample-taking. Pipe samples should be sealed on the ends, and the pipe sections placed in plastic bags or sleeves, or placed inside larger plastic tubes for protection. These safeguards are basic. There are references available in the open literature specific to the proper methodology for handling water pipe samples (for example Ref. **3,4**).

Contamination by material entering the ends of open pipes is a very real problem when sampling pipes. Shipment together with other pipes, not protected, will allow extraneous material from the outside of other tubes to enter the open ends. For example, while the amount of cross-contaminant lead potentially entering a pipe sample would be small, Dr. Russell's analysis only found lead in exceedingly small percentages in the scale, so this risk of contamination (or the risk that it is contamination) is significant. Additionally, in the case of water pipes, they should be sealed to preserve the interior scale wet during shipment, until they are received in the lab for immediate analysis. Instead, Dr. Russell left the pipes open, and then stored them in an uncontrolled environment in his garage for at least a month before inspecting them himself, and for ten months before allowing VNA and its experts to inspect them.

In our December 7, 2022 visual inspection we saw that the scale and deposits inside the pipe samples had dried and flaked, indicating that the scale had changed and deteriorated (**5**). On p.33 of Ref.**6**, Dr. Russell writes: "Like ice cores, the remaining pipe scales integrated the past corrosion and water quality conditions into the deposit remaining in the pipe." From this, it seems evident that Dr. Russell knows the importance of scale analysis but neglected to preserve evidence the scale provided, and did not undertake any but the most cursory scale analysis. Proper scale analysis may have contradicted his position that the scale was removed in 2014-15.

Contamination continued during saw cutting of the pipe to view the interior surfaces, as the teeth of the bandsaw blade would have carried cutting particles into the pipes where they would have fallen onto the interior scale layer as the saw blade passed through the pipe. That

contamination would have included the zinc galvanizing from the exterior, which would have contained lead. Dr. Russell charges that I have "provided no actual evidence of contamination" (**Ref.6**, p.27). To provide conclusive confirmation of contamination from some outside source, I would need to compare a pipe sample that had been properly sealed so it could not be contaminated – but Dr. Russell made sure that there can be no such comparison. He also did not perform any analysis to show that there was *not* contamination of the sort reasonably expected to occur given the circumstances of shipping and storage.

Dr. Russell claims that "The transport and preservation of the samples were sufficient to preserve the residual flux and the scale that covered it." (**6**) This is a very low bar for preservation because flux is difficult to remove. He lost any evidence of scale layering; it had dried and was flaking off at our visual inspection of samples. The evidence that would be available from examination of the scale is so damaged that it would be futile to analyze scale because the results would be unreliable and not representative of the conditions in the pipes in service. Furthermore, precise compositional analysis would be clouded by the likely contamination that could exceed the ppm concentrations of lead that we would be looking for.

After being cut open, the pipes were evidently stored in damp, uncontrolled conditions in Dr. Russell's garage because the cut surfaces of galvanized steel samples rusted. The internal surfaces of the steel pipes likely corroded further, too.

The problems with handling, principally resulting in the potential for contamination, mechanical damage, and sample scale degradation mean that the results of analyses already performed by Dr. Russell are unreliable.

2.2 <u>Opinion 2</u> – The handling of chain-of-custody was inadequate to ensure the integrity of the specimen sections of pipe for further analysis.

Chain-of-custody provides a history of the samples not only to ensure they are what they are represented to be, but that the effects of transport can be ascertained. During his deposition, Dr. Russell stated that the shipping container had been opened and inspected by TSA personnel (Ref.**7**, p.141), and then the container was damaged and had to be replaced (Ref.**7**, p.353), but the chain-of-custody paperwork tells us nothing about this. Samples were analyzed by a metallurgical engineer, but apparently not left in his possession at all. Dr. Russell stated the samples were stored in his garage (Ref.**7**, p.142), but then that they were stored about an hour from his house in a storage facility (Ref.**7**, p.352), neither of which were environmentally controlled. These are significant events in chain-of-custody, and something that a professional working in corrosion analysis would avoid or at least make note of.

ASTM Standard D4840 (**8**), although for liquid samples, describes processes that would be similar for metallurgical samples, including sample labeling, sealing, shipment, laboratory

handling, sample splitting and laboratory security. These processes ensure data defensibility and are also part of quality assurance for laboratories. Russell's handling of the samples does not meet this widely accepted standard in practice or spirit.

2.3 <u>Opinion 3</u> – Scale, and oxide layers in the pipe protected the underlying metal from corrosion in service, lasting throughout the exposure to Flint River water.

Water piping typically has a scale layer on the inside, mostly oxides, hydroxides and carbonate minerals. Water chemistry is controlled to allow some scale to form because it provides protection to the piping, resulting in low corrosion rates. The chemistry is optimized so that excessive scale does not form and plug the lines.

Scale in Flint pipes is illustrated in **Figure 1,** which shows scale and rust inside what appears to be steel piping. This scale would have been altered during the water crisis, but the extent of loss or thinning of the scale or the underlying pipe wall is an open question. The EPA recognized that the lead release in Flint was coming from damaged scales in lead pipes (**3**). Testing of corrosion in circulating pipe loops used sections of lead pipe with intact scales (**3**). If scales remained on the lead pipe, they would have remained on all the piping. This is the condition of pipes that existed in Flint during and after the Flint River water period in 2014-2015. The pipes were lined with scale that protected them from corrosion.

Figure 1. "Different kinds of iron corrosion and rust were found in Flint drinking water pipes. Photo credit: Min Tang and Kelsey Pieper, Flintwaterstudy.org" (**9**). The pipes appear to be steel.

2.4 <u>Opinion 4</u> – If any lead pipe surface was exposed by the loss of scale, the corrosion rate was low, and loss of thickness was minimal.

Lead service lines (LSLs) remained in a small fraction of Flint homes at the start of the Flint River water exposure (as low as 16% per Ref.**10**). The other up to 84% had non-lead service lines.

Samples of lead service lines taken during and after the Flint River water exposure showed scale was present. Williams et al. (**3**) tested sections of LSLs from Flint in a pipe rig and measured lead release for a study of corrosion control. The sections of pipe had been excavated and cut from LSLs at homes in Flint. These sections were apparently taken while on Flint River water or soon afterward (late 2015 or early 2016). The pipe sections contained scale and deposits that had built up over decades of service in Flint. <u>These deposit layers were still present following the period of use of Flint River water, providing protection from corrosion.</u> Williams' investigation showed that lead concentrations originated from dissolution of scale, not from dissolution of lead.

Williams et al. (**3**) noted that the friable, amorphous nature of the outer layer (L1) of the scale could release particulate lead, leading to elevated measured concentrations. When the particulate was filtered out of the water samples, the levels of dissolved lead were low. From a corrosion point of view, that difference is very important because the particulate is old corrosion deposit in the scale and does not represent on-going corrosion.

Similarly, Olson et al. (**11**) found scales present on the sample of lead line from Flint that they studied. They analyzed that scale to determine the amount of lead lost from it. Most of the lead released during the period of time with Flint water was released from corrosion products in the lines (**11**), so estimates of the corrosion rate from these measured concentrations of lead in Flint water samples would not be meaningful because the lead did not arise from on-going corrosion of the metallic pipe wall.

The lead service lines connected to copper or galvanized lines. There is a concern with galvanic effects at these junctions. DeSantis et al. (**12**) examined 28 lead pipe joints (60-114 years in service) and identified three distinct corrosion patterns, the greatest risk being where the lead was anodic to the adjacent pipe, but in some cases the copper pipe or brass fitting was anodic. DeSantis et al. noted that the direction and magnitude of galvanic attack is a complex combination of anode-to-cathode surface area ratio, distance between coupled metals, temperature, water flow velocity, water quality and condition of the metal surface. Thus, based on these published results, we cannot predict if galvanic corrosion dissolved either side of the junction, or by how much.

In conclusion, it is unlikely that corrosion of lead pipe was increased by the use of Flint River water, and so had no effect on the dissolved lead levels in the water.

2.5 <u>Opinion 5</u> – The copper pipe samples were typical of residential copper piping and showed no visual evidence of significant corrosion damage. Thickness measurements indicated that the piping was within the tolerance for new piping.

Dr. Russell still provides no evidence that the copper pipes at issue lost any wall thickness compared to new pipe. ASTM Specification B88 (**13,14**) provides that Type M ½-inch copper tube has a specified wall thickness of 0.028 inches with a tolerance of 0.003-inch, i.e., per the specification, new copper pipe can be anywhere from 0.025-inches to 0.031-inches thick. Nearly all of Dr. Russell's purported pipe wall measurements are 0.026-inches, within the specification range (**15**). Indeed, Dr. Russell says that "based on the review of thousands of feet of pipe," "copper pipe is **uniformly manufactured to the minimum wall thickness allowed by B88 to save the manufacturer money."** (Ref.**6**, p.28) (emphasis added). Thus Dr. Russell's own wall thickness measurements are entirely consistent with what Dr. Russell says would be expected of new copper pipe. Dr. Russell's acknowledgement that new copper pipe is "uniformly manufactured to the minimum wall thickness allowed in B88" also defeats his unsupported assertion that "it is perfectly logical to use the 0.28-inch [sic] wall thickness as the starting thickness for calculating the loss of wall thickness" (Ref.**6**, p.39).

As to Dr. Russell's single purported measurement below 0.025-inch (0.019-inches from an unidentified area of a single pipe), there are many possible causes of thin areas in piping aside from corrosion, including manufacturing variations, erosion, tooling damage, and stretching of the outside of bends of a pipe, which are naturally thinner. Dr. Russell still has not identified where he took that measurement, nor has he attempted to rule out other explanations for the result. Dr. Russell has lumped all of the possible causes of thinning together and then attributed them exclusively to corrosion during the Flint Water event. One of the objectives of a metallurgical failure analysis is to determine the causes of thinning. For example, removal of oxides and scale reveal the internal surface of the pipe where etching or pitting from corrosion can be seen, or scratches from tooling to fit-up tube ends to fittings, or fluid erosion (especially at bends), etc. Dr. Russell did not do any of this. Had he done it, likely it would undermine his claim that thinning is all due to corrosion during the 18-month exposure to Flint River water because alternative explanations would be revealed.

Dr. Russell also has not identified any basis to undermine my own wall thickness measurements. Contrary to Dr. Russell's assertions (**6**), the calipers used during the inspection were adequate quality and accuracy to perform the measurements. The digital calipers, which were purchased from Laboratory Supply Co. (not Home Depot) are accurate to ± 0.0005 inch. For the purpose here, ± 0.001 inch is sufficient. Dr. Russell reports his own measurements at the 0.001-inch level. The calipers were pre-checked with a set of feeler gauges up to 0.035-inch thickness, with full conformance to the gauge, and then confirmed

afterward. These calipers have been found to match dimensions obtained with cross-sections measured with an optical microscope when used in a corporate metallurgical lab before I began to use them for field measurements. The calipers served their function. Contrary to Dr. Russell's suggestion, my measurements were not made where there were burrs on the edge of the pipe.

In the end, Dr. Russell's own wall thickness measurements confirm that Flint River water did not corrode the copper pipes at issue because there was no evidence of any thickness loss. Dr. Russell's measurements are within the allowed range for new copper pipe, and as Dr. Russell himself asserts, "copper pipe is uniformly manufactured to the minimum wall thickness allowed by B88 to save the manufacturer money." (Ref.**6**, p.28). Dr. Russell's observation defeats his opinion that the copper pipes at issue lost wall thickness during 2014-2015. Dr. Russell's wall thickness measurements are entirely consistent with – and what Dr. Russell says should be expected for - new copper pipe.

The pipe inspection has not provided any basis for Dr. Russell to attribute corrosion, even if it had occurred, to the period 2014-2015. Corrosion losses must be calculated based on two measurements at least – one at the beginning of the period and the other at the end – and no such measurements are available. Thus, even if Dr. Russell had shown that the copper pipe samples lost wall thickness while in service (and he has not), Dr. Russell would not be able to reliably attribute lost wall thickness to the 2014-2015 time period.

2.6 <u>Opinion 6</u> – There was no evidence of corrosion damage of the copper pipe.

Dr. Russell failed to remove the oxide and scale from the copper pipe samples to perform further microscopic examination. The thin oxide layer on the surface of the copper pipes likely is not concealing evidence of any significant corrosion attack.

Pitting of copper pipe has not been reported, and the conditions in the water during the Flint River water period would not have caused pitting. The pH did not go below 7, where pitting could occur in hot water (**15**), and when the pH was greater than 8, the alkalinity was not low enough (**17,18**). Uniform corrosion would have been expected to be lower during the Flint River water period, as discussed in Opinion 8 below. Chloride concentrations would be expected to decrease the rate of any corrosion by passivating the copper surface (**35**).

The excellent corrosion resistance of copper means that release of copper to the water would be minimal and should not have exposed residents to copper concentrations that were significantly elevated.

2.7 <u>Opinion 7</u> – There was no lead contamination of the scale in samples of the copper lines at either of the two Flint homes. The copper pipes themselves were not a source of lead release through corrosion or scale reformation.

Dr. Russell's analyses of the scale and solder in the copper pipe samples found no lead (**15**). These results support the idea that they were not contaminated by lead carried from upstream. In homes with copper piping soldered with lead-containing solder, the solder would have been covered with scale, so would not have corroded. There is no need to replace copper pipes due to contamination. They will not release lead to residents' water.

2.8 <u>Opinion 8</u> – The corrosion rate of any exposed copper pipe is estimated to have been lower during the Flint River water exposure based on solubility calculations for copper. These lower corrosion rates would have meant decreased release of copper to the water of residents.

It is believed that the scale observed on the copper pipe was not disturbed during the Flint River water exposure, and that this scale would have protected the copper from corrosion. In case there were areas of the pipe where the scale was removed by some means, say erosion, then some corrosion may have occurred. An estimate of changes in copper solubility was calculated to understand the effect of the changes in chemistry during the Flint River water exposure. Data from the Flint Water Plant were entered into a spreadsheet and are plotted below. The data on pH and alkalinity have been plotted in **Fig. 2 and 3**. It can be noted that the pH increased during the use of Flint River water, and that the alkalinity was mostly higher, but with periodic decreases below 60 mg $CaCO_3$/L and a couple of extended periods below 40 mg $CaCO_3$/L.

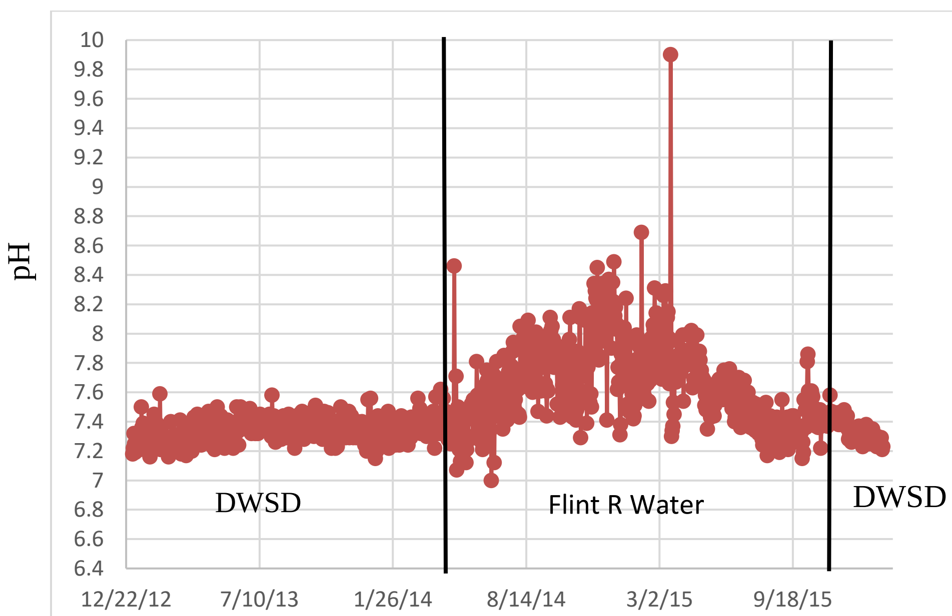

Figure 2. Measured pH from January 2013 to February 2016. The vertical black lines mark the period of use of Flint River water from May 1, 2014 to October 17, 2015.

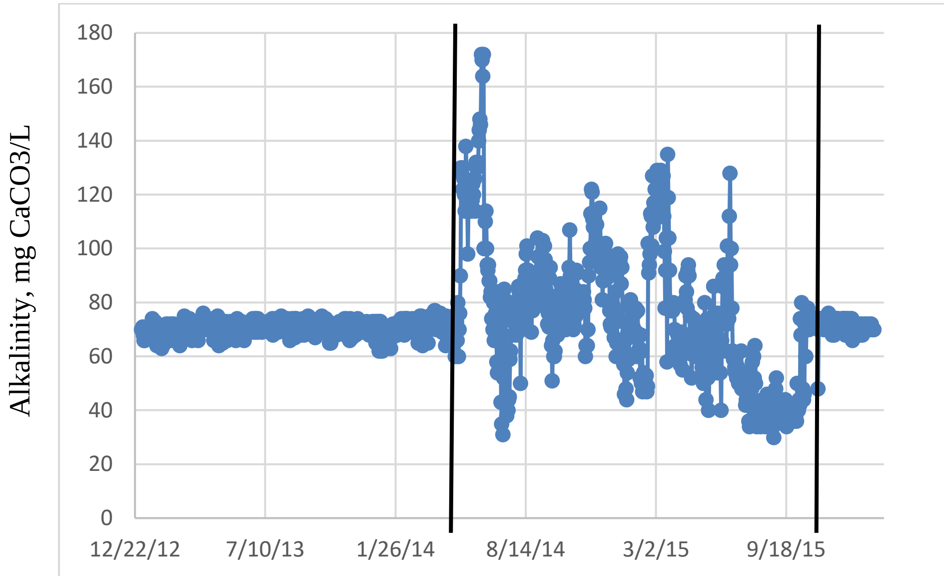

Figure 3. Measured alkalinity from January 2013 to February 2016.

Uniform corrosion of copper, as distinct from pitting, is favored in waters with low pH and high alkalinity (**17**). Copper corrosion is known to increase as pH decreases below 6. There is no record of Flint water pH falling below 7, **Figure 2**.

Orthophosphate additions are known to help reduce levels of dissolved copper in waters, and so we considered the effects of the absence of orthophosphate on corrosion of copper. The discontinuation of the use of orthophosphate during the Flint River water period was expected to have increased the copper dissolution rate. We have estimated dissolution rates for copper based on a copper solubility model by the EPA.

Lytle et al. (**19**) have presented a model for estimating the impact of orthophosphate on copper dissolved in water. The copper concentration in water closely fits the equation:

$$Cu = (56.68) \exp[(-0.77)(pH)]\exp[(-0.20)(PO_4)](DIC^{0.59}) \qquad (A)$$

Where Cu is the predicted copper concentration (mg/L), PO_4 is the orthophosphate concentration (mg PO_4/L), pH is the measured pH, and DIC is the dissolved inorganic carbon concentration (mg C/L). Values of pH, DIC and orthophosphate were obtained from the published Flint Water Plant data. The orthophosphate concentration was 0 mgPO4/L from May 1, 2014 to October 17, 2015.

The results of the model are plotted in **Fig. 5**. In the absence of data on the phosphate concentration prior to the water crisis, we used a value of 1 mg/L based on a Great Lakes Water (previously DWSD) report (**20**) that they added 1 mg/L orthophosphate, and on the measured values just after re-establishment of the DWSD water supply.

The copper solubility concentration values prior to the use of Flint River water averaged 0.60 mg Cu/L. From the plot, it is seen that there are periods during the use of Flint River water when the copper concentration exceeded the value of 0.6 mg/L, but there were also periods when it was lower. It averaged 0.47 mg Cu/L during the use of Flint River water, that is**, the copper solubility, on average, was lower in Flint River water. So, the copper solubility of any exposed copper would have been lower during the event.** Despite the wide variations in the pH and alkalinity, fortuitously, the average conditions were favorable to the copper. Less dissolution of the copper would be expected during the event than prior to it if corrosion is proportional to solubility. <u>However, the surfaces were protected by oxide and scale in both time periods, so dissolution rates would be overestimated in both cases</u>. Note how solubility drops at the end of the plot, when the orthophosphate concentration was increased.

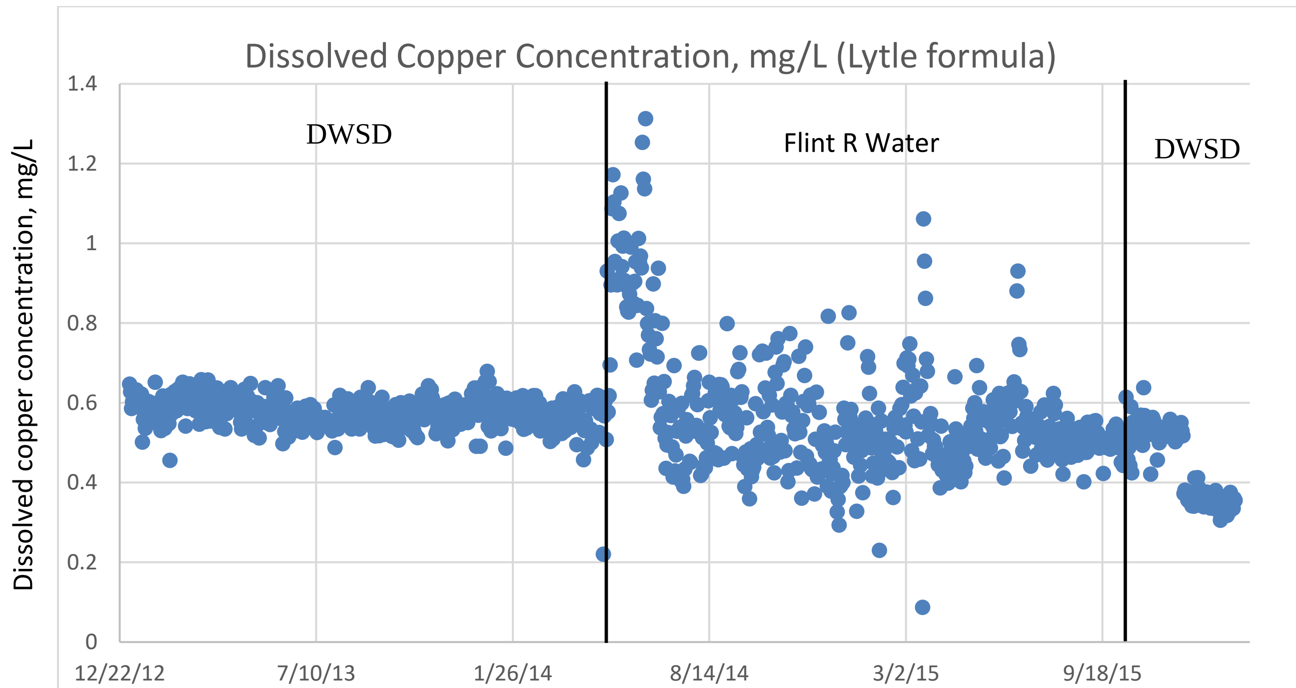

Figure 5. Estimated copper concentration from January 2013 to February 2015.

2.9 <u>Opinion 9</u> – The condition of the galvanized pipe samples was typical of residential galvanized piping after many years of service.

The condition of the galvanized pipe reflects deterioration of galvanized steel piping over many decades. Some corrosion at screwed joints, weep spots where pits have penetrated through the wall, and significant internal scaling are what we would expect anywhere. The galvanized pipe samples are evidence of long life at Flint, and are in very good condition considering their age, estimated at 84 years for the [redacted] home (**2**).

It must be emphasized that the pipe inspection does not provide Dr. Russell any basis to attribute corrosion or pitting to the 2014-2015 time period. The pitting observed by Dr. Russell could have occurred before, during, or after 2014-2015. Pipes with through-wall pitting can continue to function as part of a residence's active plumbing system, in many cases for years, because the pit fills with scale and other deposits, forming a plug. Indeed, I am not aware of any evidence that the galvanized steel pipes at [redacted] were actively leaking when Dr. Russell removed them.

2.10 <u>Opinion 10</u> - Galvanized steel pipe was protected from corrosion by thick scale.

Samples of pipe from [redacted] contained heavy scale, typical of decades-long exposure and not consistent with the scale removal and damage claimed by the plaintiffs to have happened during the use of Flint River water from April 2014 to October 2015.

Analysis of galvanized steel pipe samples from the service line at "Residence Zero" in Flint, analyzed by Pieper et al. (**21**), found scale intact in May 2015. There was no evidence of pitting in this 'worst case' location. The internal surface retained deposits containing phosphate, formed prior to the use of Flint River water. <u>Thus, the internal surface was relatively intact, suggesting that very little corrosion had occurred during the time with river water</u>. The authors did not report any evidence of pitting or sulfide scales. They attributed releases of lead and other metals to disrupted scale. The authors noted that "the high lead and iron levels observed were consistent with destabilization of lead-rich corrosion rust layers, the nature of which varied considerably with time, and with distance from the LSL."

2.11 <u>Opinion 11</u> - Corrosion rates of steel pipe were not increased in Flint River water.

Russell Bellwether 3 (Ref.**22**, p.10) states "The corrosive water provided from the Flint River increased the effective steel corrosion rate by upwards of an order of magnitude (10 times more) when compared with the DWSD water that was provided to Flint prior to the switch in 2014 (Edwards 2015). This increased corrosivity was obvious given the magnitude the increase in chlorides in a low alkalinity water (as was present after softening of the Flint River water) and the excessive red water (iron corrosion) reports throughout the City of Flint."

Dr. Russell based his claims of increased corrosion during the Flint River water period on the results of corrosion tests by Edwards' group at Virginia Tech using nails in Flint waters with and without orthophosphate (**9**). That publication is informative only as to how new nails would fare in the water during the Flint River water period. The publication by Larsen (**9**), which presented the results, is not a peer reviewed source, but rather an editorial in Materials Performance magazine. The results of Dr. Edwards' test are not relevant to what happened on old scaled pipes which have passivated with tenacious oxide over decades. In contrast to test results on new nails as a predictor of corrosion of scaled pipes, other research by Edwards (**23**) found that with no inhibitor, in 72-hour stagnation conditions, on average, old pipes had 63% lower iron release than new pipes.

Dr. Russell does not dispute that the Virginia Tech nail study is not representative because the presence of scale and corrosion deposits on the surface of galvanized steel pipes would have resulted in much lower corrosion rates. Instead, he merely asserts that "the steel utilized in nails is high quality" (Ref.**6,** p.28), without knowing whether said nails actually met the referenced spec, and ignoring the effect of scale in pipes. The ASTM Standard Specification for Nails, F1667 (**24**), in fact does not provide any specifications for composition, so the nails are not high quality materials.

The importance of oxide corrosion products and scale is well documented for Flint waters. For example, corrosion testing in the EPA test rig for Flint involved careful procedures to preserve surfaces, and then to acclimate them to water conditions in the test loop before making any measurements or conclusions (**3**). This caution points out the important role of pipe scales in corrosion, and the protection they afford as water conditions fluctuate.

It is notable that Marc Edwards' group never reported any evidence of galvanized steel pipe failures. EPA also never published studies of failures and would have had access to samples, which they surely would have studied if failures were widespread and due to the Flint River water. Dr. Russell has disclosed that EPA had no pipe samples from Flint (Ref.**7**, p.388).

2.12 <u>Opinion 12</u> – The galvanized steel pipes did not fail.

There is no evidence of failure of the galvanized steel pipes obtained by Dr. Russell. He claims extensive damage occurred in 2014-2015 (**15**), but there are no reports of this, and no repair bills have been presented for houses in Flint associated with the Flint River water event. I have searched extensively on-line for accounts of failure and found none. I consulted with a plumbing professional who works in Flint and he reported that he was not aware of increased plumbing failures during that time period or afterwards. If Dr. Russell were correct about the water conditions in 2014-2015 causing pipes to fail, then reports of pipe failure in Flint would be expected, but the evidence does not support that.

Dr. Russell (**15**) contended that the galvanized pipes at [redacted] failed because the pipes had some weep spots. He then simply assumes that the pitting occurred during the Flint River water period, with no proof at all that the weep spots did not predate the Flint River water period. Dr. Russell offers no evidence that any corrosion occurred in 2014-2015. And regardless of when the corrosion occurred, the pipes did not fail. The pipes were used for more than 6 years following 2014-2015, and were still in service when Dr. Russell cut them out. Clearly, the pipes had not failed. If tubing continues to hold water under pressure, it has not failed. The piping in question appears to date from the construction of the house in 1938 making it about 84 years old. After 1960, the owners would likely have used copper instead of galvanized to replace lines, but even if the galvanized steel pipes were installed as late as 1960, they're still very old (62 years). The galvanized steel pipe has simply reached the end of its life, and the condition of the galvanized steel pipe is entirely consistent with normal, old pipe.

Dr. Russell also found it significant that the galvanized steel pipe sheared off when his plumber tried to remove them (**15**). VNA was not present to observe the pipes shearing off, and Dr. Russell did nothing to document the process. In any event, it is not unusual for old, galvanized steel pipe to shear off if enough force is applied, particularly around threads at the end of a pipe, which are naturally thinner due to tapering and thread cutting. It is also a reckless sampling technique to wrench pipes apart, especially when the sampling party claims that the pipes are damaged in some way.

Dr. Russell stated that orthophosphate addition by the Detroit system had started in 1997 (**22**), well into the life of galvanized steel pipe. It would have pitted very quickly and failed during its years of service before 1997 if we accept his belief that lack of orthophosphate results in sudden, extensive damage.

Dr. Russell did not estimate the rate of corrosion of the galvanized steel pipe, and never exposed the surface under the oxide to see if any damage is present. The wall thickness seen where the pipes were cut longitudinally was thick and uniform. The thickness of the scale suggests that the pipe has been protected by the scale for decades.

On p.37 of his rebuttal report of March 3, 2023 (Ref.**6**), Dr. Russell states that "it is extremely likely that there is no interior galvanized coating present in these pipes…" While the zinc coating would be corroded away first to protect the steel underneath, I have seen zinc in samples of scale or on the surface underneath scale of samples of old galvanized pipe. That zinc must have been covered with scale which protected it before it dissolved to protect the steel, or it separated from the steel and was encased in scale. The absence of scale cross-sectioning and analysis by Dr. Russell meant he could not have seen any, and flaking of the scale due to lengthy, poor storage precludes further analysis. If there was zinc, then its constituent lead (from the zinc/lead alloy used in galvanizing) should be present from the

original pipe, and very, very little at that. Additionally, zinc is adsorbed in iron scale, forming a reservoir for indirect release (**25,26**) so its presence would be normal.

2.13 <u>Opinion 13</u> –Lead present in the scale from galvanized steel pipe samples was due to contamination during sectioning of the tubes or from the original galvanizing layer in the pipe, not from contamination carried there during the Flint River water period.

In his Bellwether 3 report (**22**), Dr. Russell stated that:

> "The lead levels remaining in the heavily corroded and tuberculated steel pipe sections collected from a house in Flint (and most likely at all other similarly plumbed homes having water service laterals made from lead) are excessive and present a risk to the health of the residents of Flint and require removal to protect the health of the citizens of Flint. Additionally, the current standards for lead content for drinking water fixtures are up to two orders of magnitude lower than the lead content of the installed fixtures and will likewise require removal and updating with fixtures that meet the current less than 0.25 percent lead requirement. The condition of the residual scale that remains in the pipes today, with the high lead content, is a problem that needs to be corrected immediately."

Galvanized pipe is steel with a zinc coating applied to the surface to protect it. This coating is typically only 20-85 microns thick (about 3 mils). The zinc is corroded preferentially and prevents the corrosion of the iron in steel by a galvanic action. When the zinc has been removed, the iron starts to corrode. Usually, in old pipe, we see areas with no zinc coating, and tubercles of rust and scale in places. If the scale is disturbed, then the rust is released into the water. Near the end of life of this piping, discoloration of water becomes an issue.

The presence of lead in galvanizing zinc will affect measurements of lead in scale, so lead there from manufacture must be differentiated from lead carried there by waters, or in the case of Dr. Russell's samples, on the contamination of the scale (**25**). Furthermore, we can do this because cadmium is also present in galvanizing zinc and is retained like lead – so the amount of lead from the galvanizing source can be estimated by proportion to the cadmium measured (**21,25**). Dr. Russell made no effort to determine the source of the lead.

In his report of October 2022 (**15**), Dr. Russell provided analysis results for scales scraped off of the inside of galvanized piping. In a sample of galvanized pipe from [redacted], lead was found to be 114 mg/kg. Expressed as weight percent of the deposit, this was 0.0114%. This lead was likely residual from the lead that was present in the original zinc galvanizing layer. Alternatively, the lead could have been deposited from a lead service line that was at this address prior to 2017 (after which time the service line was replaced with copper). Because Dr. Russell failed to determine the source of the lead, we have to admit the possibility that it was from the galvanizing layer or from the old LSL.

In galvanizing, the surface is coated with molten zinc. "Prime Western" zinc was typically used for this, and it has a maximum lead content of 1.4% lead (**23**). It will not be surprising to find 0.0114% lead in the scale when the original galvanizing layer contained 1.4%, about 1/100th of the content of lead in the original coating. Finally, lead from the galvanizing layer on the exterior surface could have been carried to the inside of the pipe when cutting the tubes open for visual inspection by the saw teeth as the band saw blade passed through the pipe, contaminating the interior with lead.

An alternative explanation for lead in the scale of galvanized steel pipe is that it originated from lead carried downstream from lead service lines (LSLs) for the less than 16% of Flint homes that had LSLs prior to the Flint River water period (**10**, p.6027) (now much reduced by lead line replacement). This lead could have been deposited as lead phosphate through the action of orthophosphate between 1997 and 2014, and then from 2015 to present. Russell claims that lead released from LSLs and other plumbing components was carried into residential piping and deposited. On the other hand, he asserts that the scale and oxides were sloughed off during the event, exposing the pipe to damage, so deposition seems unlikely during that time. These two claims are at odds. The observation of adherent scale in pipe samples, and the absence of evidence of any unusual corrosion supports the idea that lead, if not present from the original galvanizing layer, was deposited over many years. However, due to Russell's saw-cutting of the samples which likely contaminated the galvanized steel pipe samples with lead (see Opinion 1), we do not even know how much lead was present in the scale in pipe samples.

Corrosion of steel pipe itself cannot be a source of lead, as lead is not a significant contaminant of steel.

2.14 **<u>Opinion 14</u> – Piping in homes representing Bellwether 3 plaintiffs did not show external evidence of corrosion damage. Most had predominantly copper piping.**

Reports from seven homes provided as sites for lead inspection were reviewed (**27-33**). The inspections were primarily for evaluation of the amounts of lead in dust and paint and soil, but XRF measurements of selected piping components were performed. The tests found lead in brass fittings and in solder on the exterior of some copper piping. Pre-World War II homes were more likely to contain galvanized steel piping, and these appeared to be in very good condition. No indications of damage or pipe failure were reported.

The home at [redacted] had a lead service line on the public side and galvanized on the private side until 2017 when both were replaced with copper. At [redacted] the service line was lead (public and private sides) up until 2017 when it was changed out to copper. The homes at [redacted] and [redacted] had copper service lines (**34,36**).

Dr. Russell has not reported on or inspected the piping for these Bellwether 3 homes (**22**), but they do not support his claims of widespread corrosion. The differences between the two houses inspected as part of the Class Action ([redacted] and [redacted]) and the Bellwether 3 houses preclude any attempt by Dr. Russell to extrapolate from the [redacted] and [redacted] residences to the condition of pipes at the Bellwether 3 homes, which he never inspected. Indeed, the differences suggest that the Class Action homes are not representative of Flint homes in general.

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